Charles Darwin's Indian Ocean Experience

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Charles Darwin's time within the Pacific Basin is frequently described as a formative period in his development, while his traverse of the Indian Ocean in the first half of 1836 is much less emphasised. Yet his powers of observation remained at a high level in south-west Australia, on Cocos and Mauritius, at the Cape of Good Hope, and while at sea. 'The habit of comparison', as he called it himself, continued to be as important as ever. Themes noticeable in his earlier thinking and note-taking were consolidated during this period. He remained an avid collector of plant, animal and geological specimens and some of these specimens were to prove of appreciable significance.

KEYWORDS: Charles Darwin, Indian Ocean, HMS *Beagle*, comparison, islands, coral

INTRODUCTION

> [T]he Pacific played a central role in shaping Darwin's experience of nature and the nature of modern science. ... As the Pacific shaped Darwin, so Darwin shaped the Pacific.

So wrote R MacLeod and P E Rehbock in the preface to *Evolutionary Theory and Natural History – Darwin's Laboratory* (1994). The role of the Pacific Basin in the development of Darwin's ideas – the Andes, the Galapagos and Tahiti in particular – has been abundantly stressed. In the decade or two after the *Beagle* voyage, the contributions of the naturalists that followed Darwin further enhanced the reputation of the Pacific as 'Laboratory'. Hooker, Wallace and Huxley, all of whom became close associates of Darwin, also had experience of Pacific environments.

Notable, too, in the development of the 'Pacific Laboratory', was J D Dana, geologist on the United States Exploring Expedition (1838–1842) under Lieut Charles Wilkes (Viola and Margolis, 1985). Dana's work on coral reefs was profoundly influenced by Darwin's accounts, and the two men corresponded about coral reefs, on barnacles, and on the nature of the deep valleys of the Great Dividing Range in New South Wales (Armstrong, 1993). This expedition spent some three years in the Pacific Ocean, but expended just over 30 days hurrying across the Indian Ocean, not pausing between the Straits of Sunda and the Cape of Good Hope. And although the *Erebus*, with Joseph Hooker aboard, briefly visited the islands of the southern Indian Ocean (Kerguelen, Crozet), many expeditions saw the Indian Ocean as a barrier to be hastily traversed on the way to, or from, where it was perceived the real work was done.

Darwin entered the Pacific Basin on 10 June 1834, and the *Beagle* stood out from Hobart Town, Van Diemen's Land (Tasmania) on 17 Feb 1836, a total of just over 19 months in the 'Pacific Laboratory'. In that time Darwin had explored the Andes, speculating about the nature of their uplift, and explored several island groups – the Galapagos, Tahiti and New Zealand. He had met indigenous people on the 'fine island' of Chiloé, off the coast of Chile, as well as the Maoris, Polynesians and Australian Aborigines. He collected hundreds of specimens – rocks, plants, insects, shells and vertebrates. He wrote, on the traverse between Tahiti and Port Jackson (Sydney), the first draft of his theory of coral reefs and atolls: this was his first flirtation with the notion of gradualism. These were indeed all of consequence in the development of his ideas, but he had previously visited the Falklands, St Paul's, the Cape Verde Islands and Tierra del Fuego, as well as numerous sites on the eastern coast of South America, and on the homeward run HMS *Beagle* was to touch at the Atlantic Isles of St Helena, Ascension and the Azores. Almost all were important.

The purpose of this article is to emphasise the significance of the traverse of the Indian Ocean to Darwin's thinking. This is taken as the period between the *Beagle's* entering Princess Royal Harbour, Western Australia (6 March 1836) and her departure from Cape Town on 18 June, both dates exclusive, a total of just 100 days; a short period compared with the Pacific sojourn, but over three times as long as USS *Vincennes* on the US Exploring Expedition. It thus includes his explorations of the 'continental' environments around King George's Sound in south-west Australia and at the Cape of Good Hope, as well as visits to the Cocos (Keeling) Islands and Mauritius (which Darwin sometimes refers to as the Isle de France). Just under half of this time was on land, or at anchor close to land.

Table 1. Time spent on land and at sea during HMS *Beagle's* Indian Ocean Traverse.

Locality	Dates (1836)	Total Days
King George's Sound	7–14 March	7
King George's Sound to Cocos	15 March – 1 April	18
Cocos	2–11 April	10
Cocos to Mauritius	12–29 April	17
Mauritius	30 April – 9 May	10
Mauritius to Cape	10–31 May	21
Cape of Good Hope	1–17 June	17
	Total	100

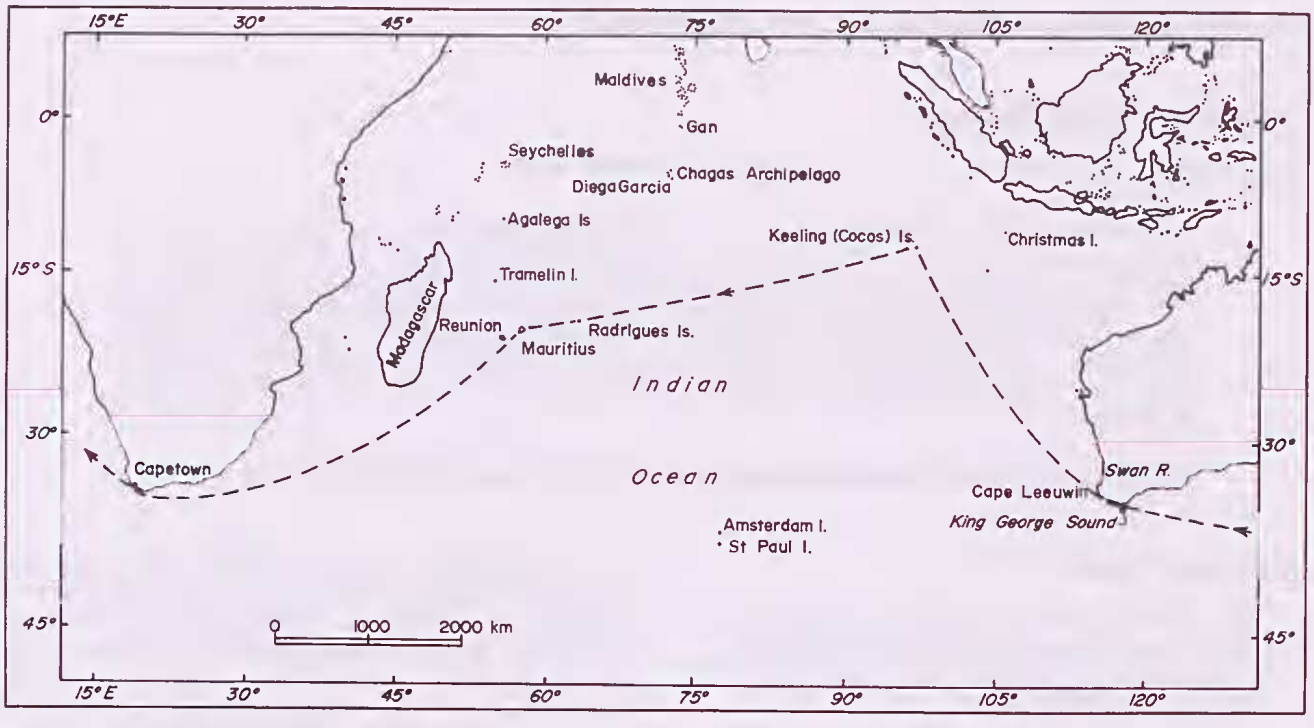

Figure 1. Route of HMS *Beagle* across the Indian Ocean.

THE INDIAN OCEAN EXPERIENCE

Powers of Observation, an Eye for Detail and the 'Habit of Comparison'

Darwin did not like the sea, and was frequently sea-sick; indeed at one time considered abandoning the voyage. It would not be surprising if Darwin was feeling wearied towards the end of the voyage, and there is some evidence that he collected specimens less assiduously than earlier. But his eye for detail was as good as ever. Moreover, it can be seen that he was arranging some of his material around conceptual frameworks that were to be of importance to him later.

When the ship was 50 miles (80 km) west of Cape Leeuwin, on 18 March 1836, he describes what he called *Confervae* – filamentous algae or phytoplankton. His account provides a good example of the level of detail typical of his notes (Figure 2). He:

> ...observed the sea, covered with fine particles, as if thinly scattered with fine dust. Some water being placed in a glass, with an ordinary lens, the particles appeared like equal sized fibres of any white wood. On examination under higher powers, each particle is seen to consist of from 10–15 cylindrical fibres. These are loosely attached side by side all together; their extremities are seldom quite equal, a few projecting at each end. The bundle was about 1/50th of [an] inch, but any separate fibres rather less, perhaps 1/60th. The color a very pale brownish green. Each separate fibre is perfectly cylindrical & rounded off at both extremities .... (Cambridge University Library Darwin Archive [CULDA] 31.2/349)

During the voyage Darwin was constantly comparing the observations in one locality with those he made elsewhere. It was this comparative approach that was in no small measure the key to his success. He did this frequently in his traverse of the Indian Ocean. On the back of the above note he wrote:

> On passage from Mauritius to C of Good Hope Lat 37° 30'. Sea with the green flocculent tufts & [illeg] dust, during a calm day in very great quantities. Must be a most abundant marine production.

Here is his account of the robber crab (*Birgus latro*) (Figure 3) on the Cocos (Keeling) Islands:

> These monstrous crabs inhabit in numbers the low strips of dry coral land; they live entirely on the fruit of the cocoa nut tree. Mr Liesk informs me he has often seen them tearing, fibre by fibre, with their strong forceps, the husks of the nut. This process they always perform at the extremity, where their three eyes are situated. By constant hammering the shell in that soft part is broken & then by the aid of their narrow posterior pincers the food is extracted I think this is as curious a piece of adaptation and instinct as I ever heard of. The crabs are diurnal in their habits; they live in burrows which frequently lie at the foot of the trees. Within the cavity they collect a pile, sometimes as much as a large bag full of the picked fibre & on this they rest. At night they are said to travel to the sea where the young are hatched, and during the early part of their life they remain. ... Their flesh is very good food. ... They are exceedingly strong. The back is coloured dull brick red: the under side of the body & legs is blue, but the upper side of the legs clouded in dull red. In the 'Voyage par un Officier du Roi' to the Isle of France there is an account of a crab that lives on Cocoa nuts in a

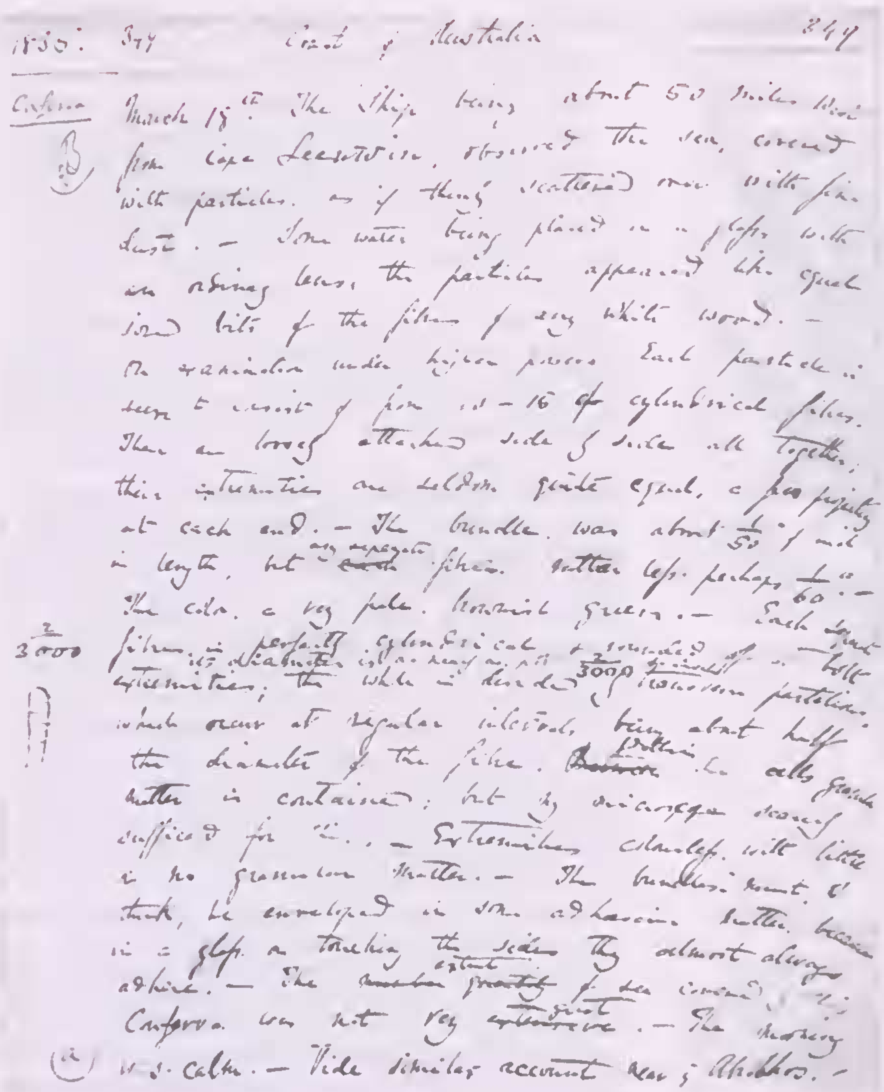

Figure 2. Charles Darwin's notes on Confervae, 50 miles (80km) off Cape Leeuwin, Western Australia, 18 March 1836 (the year at the head, 1835, is of course an error). Cambridge University Library.

small island North of Madagascar: probably it is the same animal ...

> Mr Liesk informs me that the crabs with swimming plates to posterior claw employ this tool in excavating burrows in fine sand and mud & he has repeatedly watched the process. (CULDA 31.362)

Here is Darwin the observer at his best. He describes the organism accurately; most of his observations have been confirmed in modern studies (eg Drew, *et al*, 2010). He enlivens his account with information from the observations of a resident of the islands, and material from a book to which he had access aboard the *Beagle*, but clearly separates his own observations from those of others. He gives as much attention, or more, to the behaviour of the creature as to its appearance: feeding and burrowing are described in detail, along with the lining of burrows with fibre. Breeding and daily rhythms are mentioned. The organism is related to its habitat – coconut palm groves, growing in sandy soil adjacent to the beach. The account strikingly integrates the animal's morphology with its habitat and behaviour. There are signs of the comparative approach that was so fundamental to Darwin's work. He refers to 'adaptation', a key component of his evolutionary thinking, and 'instinct' presaging his works on animal behaviour, such as *The Expression of the Emotions in Man and Animals* (1872).

In both southwest Australia and in Africa Darwin made extremely detailed geological observations. His first impression of King George's Sound was of the 'bare smooth conical hills' similar to those he had encountered in South America; he continued 'I at once suspected that the observation of Humboldt of the frequency of the form in hills of gneiss-granite, would be verified in this part of Australia.' (Darwin had been reading Alexander von Humboldt's *Personal Narrative* of his journey to South America throughout the voyage, and was profoundly influenced by it. Ref: CULDA 38.864-5). His descriptions of the granites and granite landforms of the Cape were just as detailed:

> The granite is coarse-grained & contains very large crystals of feldspar; it is in many parts traversed by veins; ... it contains balls of a dark color which consist of an aggregation of minute scales of black mica. (CULDA 38.902)

Darwin was one of the first to identify the origin of that characteristic African landform the *kopje* –

Figure 3. Coconut or robber crab, from *Dictionaire D'Histoire Naturelle*, 1849.

appreciating that they were similar to the forms occurring in Australia. The massive rounded boulders formed through the decomposition of granite, and the spheroidal weathering of the resulting corestones.

> The granite is subject to extreme decomposition, & hence, when protected is covered by a great thickness of rock, reduced into the state of soil. At the village of Paarl there are some extraordinary fine examples of loose balls of enormous size lying on the summits of the base mammiform hills of granite. Parallel & vertical fissures cross the mountains in directions at right angles to each other. These may now be seen of various widths, & it would appear that the great balls are only the remnants of original cubical masses. Besides the general description circumscribed patches of the granite yield to the weather, much more readily than the adjoining parts. As we see in some granites spherical masses projecting outwards from processing a harder & slightly different structure, so here cavities exist on the sides of steep rocks section; From the thinness of the overhanging lip, or front it appears certain, that no other cause than the quiet action of the weather has removed the central parts. A very large hollow, forming a cave, exists in the lower surface of one of the great balls on the Paarl. — This globular mass is perhaps about 30 ft high, it rests on several points, within which is a smooth arched cave, frequented by cattle. On the sides of some steep masses, the granite is worn away, into extensive shallow cavities of irregular forms, which resemble the defective parts, of any mass of cast metal. (CULDA 38. 902-4)

This detailed study of weathering processes shows that Darwin clearly understood the long periods over which geological processes operate. He was by this time fully cognisant with Charles Lyell's doctrines of uniformitarianism, set out in *Principles of Geology* (1830–1833), which he had in his possession. And it is clear from his notes that Darwin compared his geological observations of King George's Sound with his impressions of the rocks and landforms of the Cape of Good Hope and was able thereby to generalise about the processes in operation.

Human Communities and the Cultural Landscape

Yet it was not just in his geological and biological enquiries that reveal Darwin as both a first rate observer and one with the ability to integrate and see the 'big picture'. He had little knowledge of anthropology – and indeed this science was not well developed. Nevertheless he was curious about the human communities with which he came into contact often making extensive notes about their customs and traditions. Darwin's detailed description of an Aboriginal corroboree at King George's Sound was given in a previous issue of this journal (Armstrong, 2009). On Cocos he witnessed what seems to have been a funeral ritual, and he describes the manner in which the Malay people caught turtles and fish.

In Mauritius and South Africa he was curious about the many races of humankind he encountered and the way in which they got along together – he had some astringent criticisms of British colonial policy. 'Cape Town is a great inn' he wrote in a letter to his sister (CULDA 97 [ser.2]:32-3) and Burkhardt and Smith, 1985, 493) The Europeans were English, Dutch and French, with 'scattered people from other parts'. There were Malays in significant numbers, but 'the number of negroes is not very great.' He deplored the manner in which the Bushmen were 'the ill-treated aboriginals of the country'. His diary entry for 30 April 1836 says of Mauritius: 'One of the most interesting spectacles in Port Louis is the number of men of various races'. The Indians, he noted, were 'noble looking' and 'imposing'. He seems sympathetic to the 'poor man' who was 'a confirmed opium eater, of which fact his emaciated body & strange drowsy expression bore witness.' The influence of his Edinburgh medical training is perhaps apparent here both in his sympathetic approach and appreciation of symptoms. He also deplored the manner in which the Malay people on Cocos were held in a type of serfdom. Bigot he was not.

In Mauritius, at the Cape of Good Hope and in Cocos he composed almost lyrical descriptions of landscapes and the manner in which the human community interacted with them. Here are his first impressions of Mauritius, seen from the deck of the *Beagle*, 29 April 1836:

> The sloping plain of the Pamplemousses, scattered over with houses & coloured bright green from the large fields of sugar cane, composed the foreground. The brilliancy of the green was the more remarkable because it was a colour which

> generally is only conspicuous from a very short distance. Towards the centre of the island groups of wooded hills arose out of the highly cultivated plain, their summits, as so commonly happens with ancient volcanic rocks, being jagged by the sharpest points. Masses of white clouds were collected around these pinnacles, as if merely for the sake of pleasing the stranger's eye. (*Diary*)

Coral Reefs and Atolls

The genesis of Darwin's 'Coral Atoll Theory' lies firmly in the Pacific. Correspondence with a Mr R E Alison, in June 1835, while he was still in South America, suggests that Darwin was speculating on the possibility of the 'sinking of land' in the 'Pacific islands', compensating perhaps for an uplift or a rising on the Pacific coast of South America (CULCA 36.1: 427 and Burkhardt and Smith, 1985, 450). On the *Beagle's* voyage westwards across the Pacific, he seems to have climbed aloft, and looked down onto the lagoons of atolls from quite close at hand:

> ... from the Mast-head it was possible to see at Noon Island across the smooth lagoon to the opposite side. The great lake of water was about 10 miles wide. (*Diary*, 13 November 1834)

At Tahiti (15–26 November 1835) he made a careful study of the relationship of the coral reefs to the main shoreline both for the islet of Eimeo (now Moorea) and for Tahiti itself. He also looked at the detailed ecology of the reefs and their microtopography, noticing that coral growth was most vigorous on the outer, wave-splashed edge of the reef. He appreciated that coral would only grow within '25 to 35 fathoms' of the surface (approx 40–65m), and noted how steeply the sea floor sloped away a relatively short distance from the shore. A few days later, the ship passed, but did not land on, the archepelago of Aitukaki (Darwin and his captain, FitzRoy refer variously in their writings to Whytooacke, Whylootake, or Waiutaki), which represented...

> A union of two prevailing types of structure... A hilly irregular mass was defined by a well defined circle of reefs, which in great part have been converted to narrow strips of land, which [Captain James] Cook calls them half-drowned.... (*Diary*, 3 December 1835)

This appears to be Darwin's first written indication of an appreciation of a link between atoll formation and 'drowning': it is interesting that there is a link with Captain Cook.

It was probably shortly after this, but before his arrival in New Zealand on 21 December 1835, that Darwin penned his 23-page memorandum entitled 'Coral Islands' (CULDA 40/5). Here we see the first coherent expression of his notion that fringing reefs (where the coral reefs are attached to the shore), barrier reefs (where the island is separated from the reef by a moat-like lagoon) and atolls (Darwin often used the term 'lagoon islands') are members of a continuous series, one form progressing into another through subsidence (or drowning).

Darwin therefore developed his Coral Atoll Theory long before he actually had his feet on a real atoll!

In his *Diary* entry for 12 April 1836, written shortly after the *Beagle* had departed from the Cocos (Keeling) islands in the eastern Indian Ocean, Charles Darwin wrote:

> I am glad we have visited these Islands; such formations surely rank high amongst the most wonderful objects of the world. It is not a wonder that first strikes the eye of the body, but rather after reflection the eye of reason.

There is a certain triumphalism in this: Darwin seems to be appreciating his own 'eye of reason'. It was at Cocos that the Coral Atoll Theory 'came together'. He was able to apply what had thitherto been largely a theoretical construct to a real world example of an atoll or 'lagoon island' (Figure 4). He wrote extremely detailed notes, both on the geomorpholgy of the coral reefs and the

Figure 4. Inner lagoon, Cocos (Keeeling) Islands.

islands, and on the ecology of the corals themselves. He drew neat cross sections across the reefs, islands and lagoon (CULDA 41). The officers of the *Beagle* conducted an offshore survey and it was noted that the seabed sloped away very steeply from the island shore. No bottom was found some 2200 yards (approx 2 km) from the breaking waves, with a line some 7200 feet in length..

In his *Diary* entry for 12 April, the day of the ship's departure from Cocos, Darwin summarised his ideas as follows – much more succinctly than in the earlier manuscript:

> ... we must consider this island as the summit of a lofty mountain. ... If the opinion that the rock-making Polypi continue to build upwards as the foundation of the Isd from volcanic agency, after intervals, gradually subsides, is granted to be true, then probably the Coral limestone must be of great thickness. We see certain Isds in the Pacifick, such as Tahiti and Eimeo ... which are encircled by a Coral reef separated from the shore by channels & and basins of still water. Various causes tend to check the growth of the most efficient types of Corals in these situations. Hence, if we imagine such an Island, after long successive intervals to subside a few feet, in a manner similar but with a movement opposite to the continent of S. America, the coral would continue upwards, rising from the foundation of the encircling reef. In time the central land would sink beneath the level of the sea & disappear, but the coral would have completed its circular wall. Should we not then have a Lagoon Island? Under this view, we must look at a Lagoon Isd as a monument raised by myriads of tiny architects, to mark the spot where a former land lies buried in the depths of the ocean.

All this material was combined into the elegant, very thorough case-study of the Cocos Islands that comprises the opening chapter of *The Structure and Distribution of Coral Reefs* (1842), first volume of *The Geology of the Voyage of the* Beagle. The fact that he commenced the work with this case-study implies that he considered his sojourn on Cocos as providing an important key to his study of coral reefs and atolls.

Darwin continued his work on coral at Mauritius, some three weeks later.

> On the NW, W & SW of the islands coral rock such as [is] now forming the reefs is commonly found above the reach of the very highest tides ... To the northward of Port Louis the surface of the country to a height of 30 or 40ft, & to a considerable distance inland is coated by a bed of partially cemented fragments of stony branching corals ... the rock is composed of precisely the same materials such as are lying on the beach. ...
>
> The elevation above the mean level of the sea appears considerable to exceed that of the reefs in the Pacifick; hence I suspect it is owing to the rising of the land which has affected the whole Island. (CULDA 38.885-898)

Darwin was able to compare the topography and ecology of reefs in the Pacific, and at Cocos – where he felt certain that generally the land had fallen relative to the sea – with the situation on Mauritius where he had strong evidence that the opposite was the case. In his book of Coral Reefs he provides a map showing those areas where he felt that submergence had occurred and those dominated by emergence. Had the experience of the Pacific Laboratory not been supplemented by studies of the two islands in the Indian Ocean Darwin's work on coral reefs would have had major lacunae, and his first experimentation with the notion of gradual change in the environment less successful. We may note in passing that in his investigation of reefs he not only emphasises Lyellian gradual change, but the idea of a dialogue between organisms (the coral polyps) and their environment: a notion fundamental to his later work.

Island Biotas and Long Distance Dispersal

Darwin recognised the depauperate nature of island biota at a number of the islands and archipelagoes he visited during the voyage. On Cocos he describes the 'vigorous' vegetation – a response to the tropical climate. But he noted:

> Besides the Cocoa nut which is so numerous as to first appear the only tree, there are five or six other kinds. One called the Cabbage tree grows in great bulk in proportion to its height & has an irregular figure ... Besides these trees the number of native plants is exceedingly limited: I suppose it does not exceed a dozen. (*Diary* 2 April 1836)

The 'Cabbage tree' was *Scaevola sericea* (*Scaevola Koenigii* in John Henslow's account of the Cocos collection of plants – Henslow was Darwin's friend and botany teacher at Cambridge). It remains one of the most conspicuous plants on the archepelago, forming a loose shrubby barrier along the shores. Darwin's count of the plant species diversity was an underestimate, but he was right in principle: in comparison with the biota of the forests of South America, or even Australia, it was poor. It was the same for animals. 'There are no true land birds' he said, 'a snipe and a land rail' being the only waders, all other species present being 'birds of the sea'. The 'snipe' was probably the ruddy turnstone (*Arenaria interpres*), the land rail a unique subspecies of the buff-banded rail (*Rallus [Gallirallus] philippensis andrewsi*), now only found on the tiny atoll of North Keeling, which HMS *Beagle* briefly surveyed on 12 April 1836, but no landing was made, Darwin simply noting: 'This likewise is a small Lagoon Isd, but its centre is nearly filled up.'

He continued:

> Insects are very few in number: I must except some spiders & a small ant which swarms in countless numbers at every spot & place. (*Diary*, 2 April 1836)

Significantly Darwin again clearly distinguished between the number of species, from the number of individuals. A small note kept with Darwin's zoological annotations lists 12 species, including flies, ants, a couple of species of moths and a beetle. When writing the visit up for *The Voyage of the Beagle* he amends the total to 13. He notes also a single species of lizard. In his writings on the plants and animals of the Cocos (Keeling) archipelago words such as 'paucity', 'scanty', 'few' and 'only' occur.

Not only did he appreciate the low biodiversity of the island, there is evidence that he gave at least some thought to the possible means of dispersal of organisms to the islands. Darwin handed over the plant specimens he collected at Cocos to Professor Henslow and, in 1838, they were described in an article in *Annals of Natural History*. In this paper Henslow wrote: 'Mr Darwin heard of the trunks of trees, and of old cocoa-nuts being washed on the shore'. Darwin could hardly have missed finding seeds and other organic debris along the tide-line of Horsburgh, Direction and Home Islands, all of which he visited. He drew attention in his *Diary* to the abundance of seabirds, although he did not, *at the time* seem to have speculated that these might have been dispersal vehicles, although he paid considerable attention to this point later. Nevertheless in editing his diary for publication as *The Voyage*, he wrote that the archipelago 'had quite the character of a refuge for the destitute'. This implies both the idea of the paucity in the biota in terms of species numbers, and the idea of a long and difficult journey for those that eventually became successfully established. He continued:

> As the islands consist entirely of coral must at one time have existed as mere water-washed reefs, all their productions must have been transported here by the waves of the sea.

These words, however were written after his 'conversion' to an evolutionary outlook in the (northern) spring of 1837. By then he appreciated the importance of the link between long-distance dispersal and evolution: if all life on earth had a common origin, or was ultimately derived from a few simple forms, the biotas of remote islands must have been derived from elsewhere.

There are a couple of other observations that may have brought the subject of long distance dispersal into his mind while at Cocos. In his annotations on coral he noted the presence of 'small pumice pebbles on beach from Sumatra, like the seeds'. Lumps of vesicle-filled volcanic material are frequently found on the shores, having floated there from volcanic eruptions in Indonesia (I myself found several on the shore of Home Island).

Further he records collecting 'A piece of a well rounded boulder of compact greenstone [dolerite] found in the coral breccia of the Northern Isd: in possession of Capt. Ross'. Captain Ross, the proprietor of the islands, was away at the time of Darwin's visit, so the fragment of rock must have been handed over by Mrs Ross or Mr Liesk. In *The Voyage* the original boulder is described as being 'rather larger than a man's head' and on the basis of comparison with descriptions of similar phenomena mentioned by other authors the suggestion was offered that it had arrived on the lonely islet of North Keeling amongst the roots of a far-travelled tree. Again evidence – as he saw it – for the reality of long distance dispersal.

Despite his detailed geological notes, Darwin's observations on the plants and animals of Mauritius are less rigorous. He admits in his notes that his attention wandered; he wrote: 'since leaving England I have not spent so idle and dissipated a time'. He collected few specimens, apart from a very few insects and a frog.

This last was in due course identified and depicted in volume 5 of *The Zoology of the Voyage of the* Beagle (Thomas Bell, 1843) as *Rana mascariensis* (now known as *Ptychadena mascareniensis*: the Mascarene grass frog or Mascarene ridged frog). Darwin found 'this pretty species ... on swamps near the sea'; always interested in animal behaviour and locomotion he commented on 'the extraordinary height of its leaps.' Although Darwin cannot have known much of its distribution when he collected it, Bell noted that it had 'also been found in the Seychelles, Madagascar and the Island of Bourbon [Réunion]'. Darwin seems to have deduced from this that it had been introduced: recent studies, including DNA testing confirm that he was right (Staub, 1993, Vences, Kosuch *et al* 2004). In *Natural Selection*, the massive 'big species book', written 1856–1858, but unpublished until 1975, of which *On the Origin of Species* was a 'digest' he declaimed:

> It would be superfluous to give the cases amongst my notes of the enormous increase of Birds, fish, frogs, snails & insects, when turned out into new countries: the one island of Mauritius would afford striking instances of all these classes except fishes. (Chapter 5)

He used the frog example in *On the Origin*, but with a slight twist.

> The general absence of frogs, toads and newts on so many oceanic islands cannot be accounted for by their physical conditions; indeed it seems that islands are particularly well fitted to these animals; for frogs have been introduced into Madeira the Azores and Mauritius, and have multiplied so as to become a nuisance. (Chapter 12)

Darwin pointed out that these animals and their spawn are soon destroyed by sea water, so their transport by sea would be rare. Evolutionary theory, emphasising that life begets life and that living things can only reach remote islands by long distance dispersal, explains their absence. 'But why, on the theory of creation, they should not have been created there, would be very difficult to explain.'

CONCLUSIONS

Charles Darwin spent three and a half months within the Indian Ocean Basin. His powers of observation of plants, animals, marine organisms, rocks, landforms and human communities remained at a high level. As he did earlier in the voyage, he frequently used the comparative method. His traverse allowed him to confirm ideas that he had generated elsewhere, such as the Coral Atoll Theory, applying it to Cocos, and slightly modifying it to take account of the evidence of rising land levels he noticed in Mauritius. He compared the rounded granite topography of King George's Sound with the *kopje* landforms around Paarl at the Cape, thus entrenching the Lyellian views of gradual change ever more firmly in his mind. He had already commented on the relatively low species diversity of island groups such as St Paul's in the Atlantic and Tahiti in the Pacific. His observations on Cocos, and perhaps to a lesser extent Mauritius confirmed this notion; there also seem to have been early stirrings of the idea of long distance dispersal. He did not link the ideas of low diversity, evolution and dispersal until later, but the foundations were

established. He captured a frog on Mauritius, only later understanding its significance.

The Pacific was of course significant to his development, but not all-important. The Indian Ocean experience can be seen as an early stage the of the thoughtful process that continued in the two years following his return to England that led to his insight into natural selection.

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Bibliographic Note. Nora Barlow's 1933 transcription of Darwin's Beagle *Diary* was used – this is the most widely available version, although there are others. I used a recent reprint of the first edition of *On the Origin*. Similarly I used a modern reprint of the 1860 edition (almost identical to the 1845 printing, but with significant differences from the 1839 version) of *The Voyage* (ie *Journal of Researches*). Although I inspected some of Darwin's original field notes in Cambridge, many of these are now available in Darwin Online (http://darwin-online.org.uk), and I checked my own transcriptions against these.